Atmosphere and Severe Weather

Chapter 9

Energy

- **Radiation from Earth– Terrestrial Radiation**
  - Long wave Radiation – about 4 micrometers
- **Solar Radiation is at a constant level**
- When it hits the Earth's atmosphere,
  - **Some reflected back**
  - **The rest passes through the Atmosphere to be transformed into different energies.**

Energy, Heat and Temperature

- **Understanding Energy is fundamental to understanding severe weather**
- Difference between **Heat** and **Temperature is the how the energy is used**
  - **Energy**
    - **Kinetic energy -- internal energy of molecule movement**
  - **Temperature**
    - **Temperature** – the average **kinetic energy** of the molecules in a substance – ***sensible heat***
  - **Heat – energy that transfers from on object to another because of the difference in temperature. *Latent heat***

Types of Latent Heat

- **Latent Heat**
  - **Storage or release of energy**
    - **Evaporation- liquid water changes to gases, energy is released, cooling happens**
    - **Condensation- gaseous water vapor turns to liquid energy is stored, heating happens**

Heat Transfer

- **Conduction**
  - **Movement of heat energy from one molecule to another without changes to their relative positions**
- **Convection**
  - **Heat is transferred from one point to another by the predominately vertical circulation of fluid, such as water or air.**
- **Radiation**
  - **Wavelike energy that is emitted by any substance that posses heat**
- The heat transfers from a radiating heat coil through a metal pan to the water, moving the molecules in the water to a boil

Earth's Energy Balance

- **The Earth receives Solar Energy everyday**
  - This energy sustains the Earth

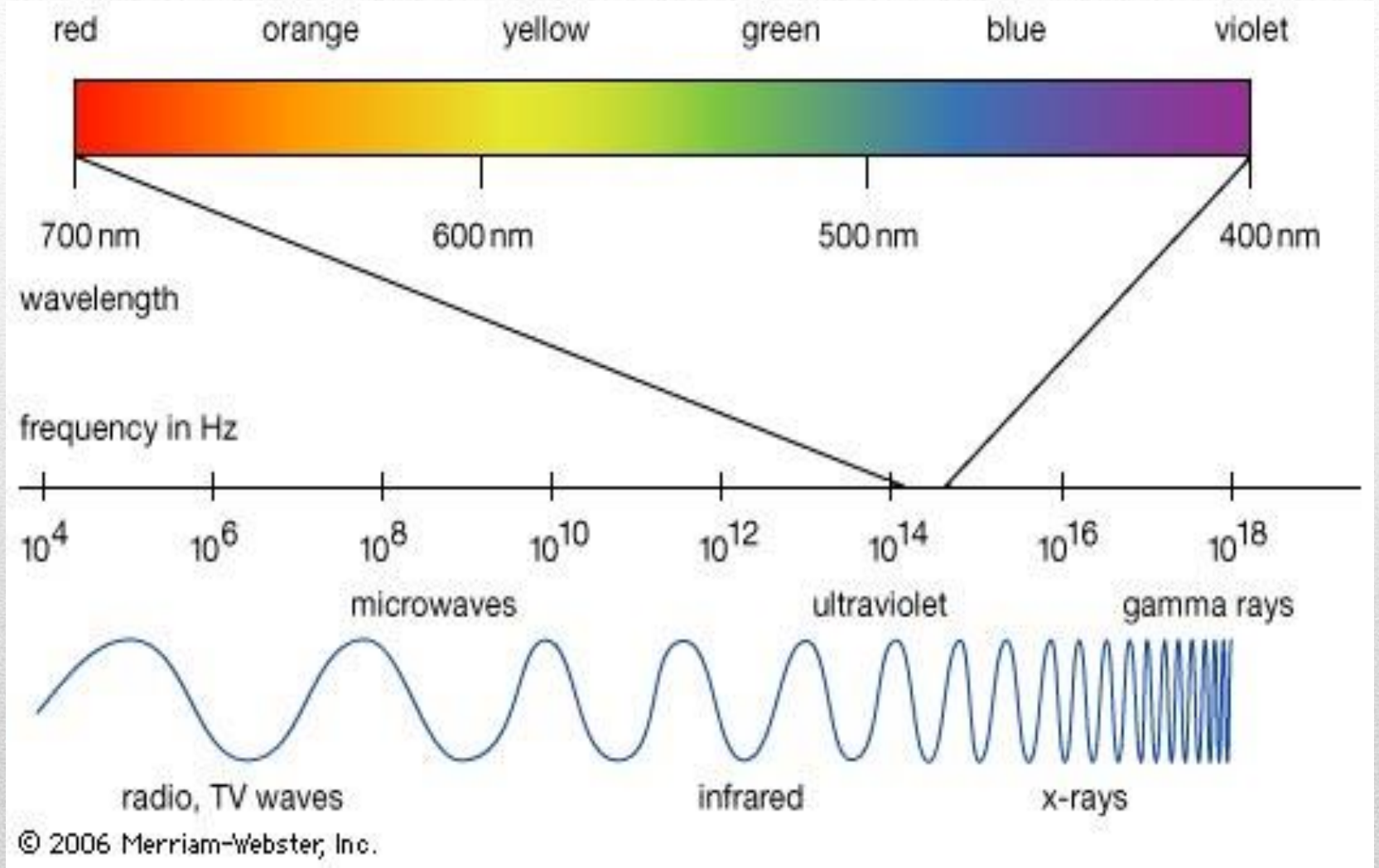
- When this energy hits the Earth's atmosphere
  - **Some reflected back**
  - **The rest passes through the Atmosphere to be transformed into different energies.**
  - **This is short wave Radiation**
- The energy the Earth reflects back is called **Terrestrial Radiation**
  - **Long wave Radiation**

Basic Heating & Cooling Processes in the Atmosphere

- **Radiation or Emission**
  - The process by which **electromagnetic energy is emitted from an object**
    - **The hotter the object the more radiation it emits**
- **Absorption**
  - The **assimilation of electromagnetic waves by striking an object**.
    - **Different objects have different absorption abilities**
- **Reflection**
  - The **ability of an object to repel electromagnetic waves without altering either the object or the waves**

Heating of the Atmosphere

- **Global Energy Budget**
  - **100 units of Solar Radiation hits the atmosphere**.
    - Some absorbed
    - Some reflected
    - Some radiated
  - **Total units radiated out 100 units**
  - **Albedo**
    - **The reflective value of an object**
      - The higher the **Albedo value** the more radiation the object reflects.
- The **atmosphere is heated by *Earth radiation*** rather than the sun radiation.


red
orange
yellow
green
blue
violet
700 nm
600 nm
500 nm
400 nm
wavelength
frequency in Hz
10^4
10^6
10^8
10^{10}
10^{12}
10^{14}
10^{16}
10^{18}
microwaves
ultraviolet
gamma rays
radio, TV waves
infrared
x-rays
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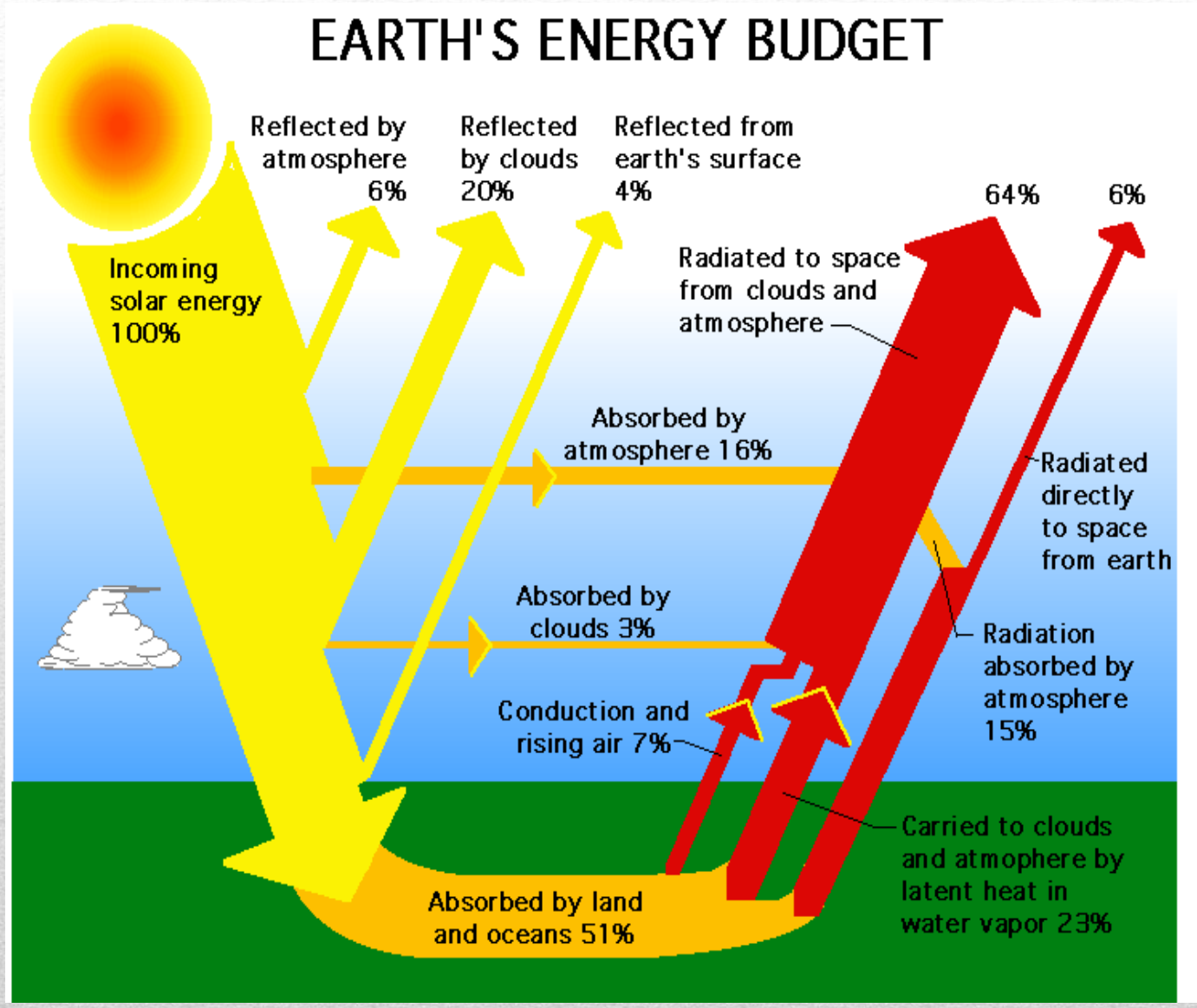
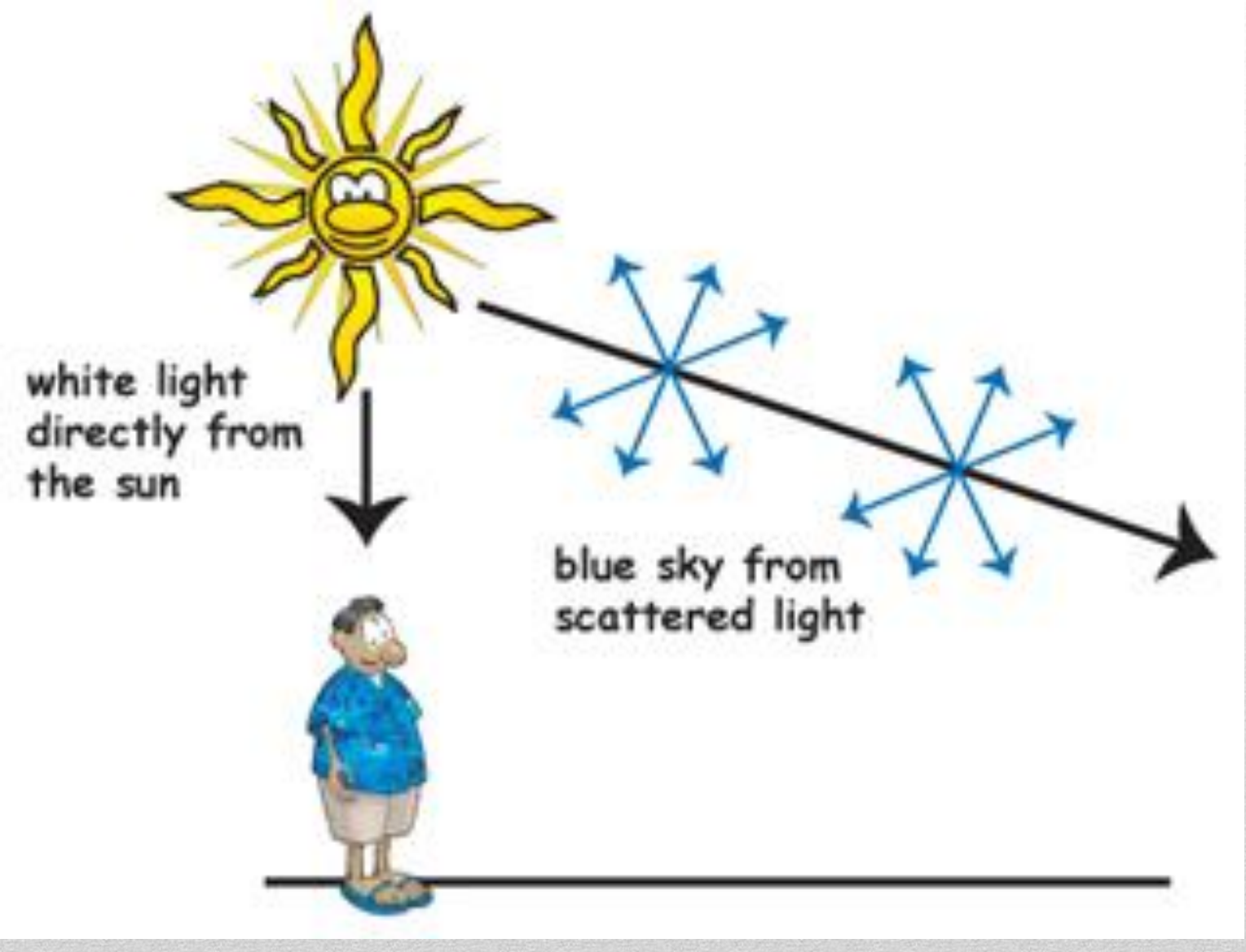

EARTH'S ENERGY BUDGET
Reflected by atmosphere 6%
Reflected by clouds 20%
Reflected from earth's surface 4%
64%
6%
Incoming solar energy 100%
Radiated to space from clouds and atmosphere
Absorbed by atmosphere 16%
Radiated directly to space from earth
Absorbed by clouds 3%
Radiation absorbed by atmosphere 15%
Conduction and rising air 7%
Carried to clouds and atmophere by latent heat in water vapor 23%
Absorbed by land and oceans 51%

Basic Heating and Cooling Processes in the Atmosphere

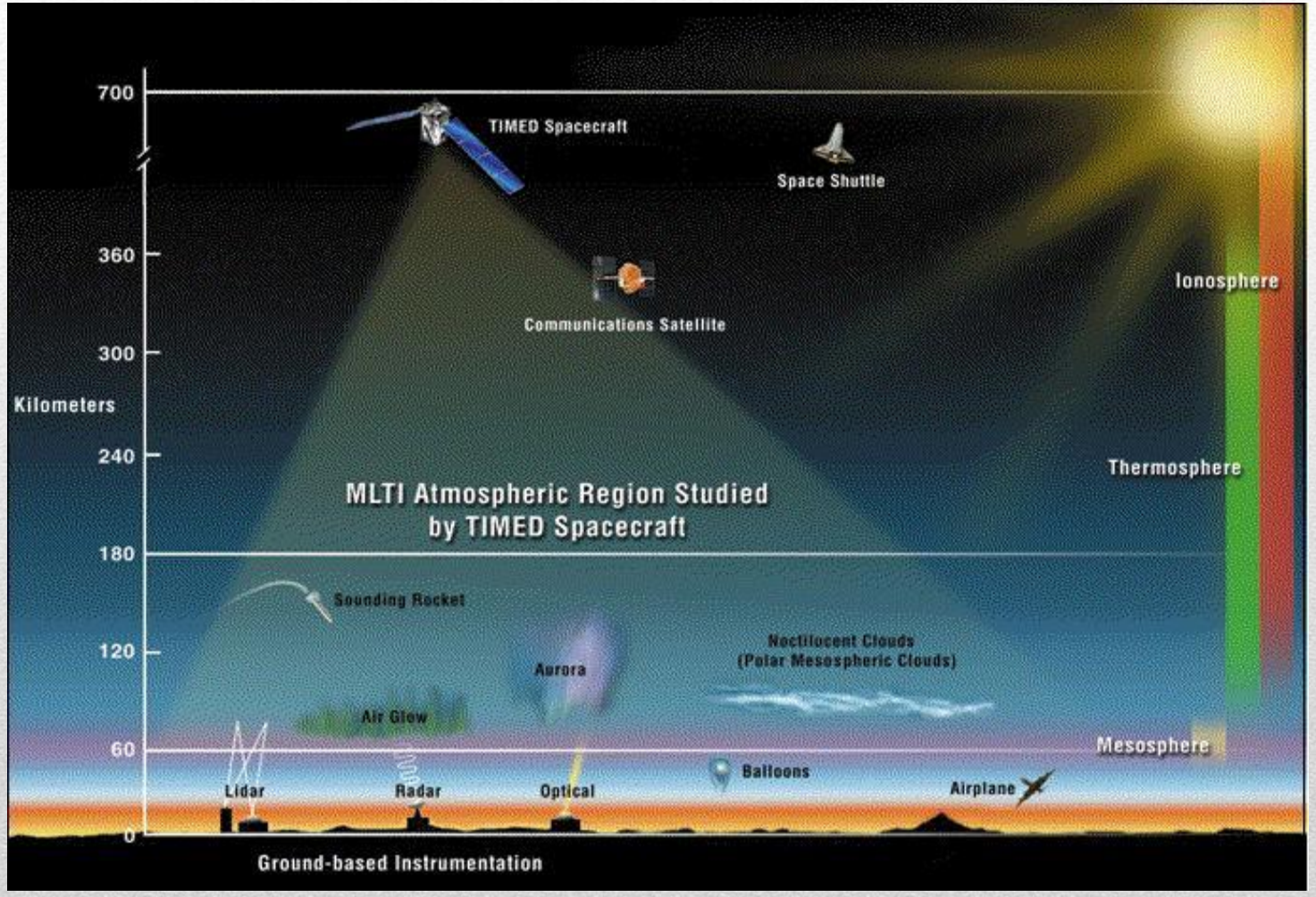
- **Scattering**
  - The **act of deflecting or redirecting light waves** with gas molecules and particulate matter in the air.
  - Rayleigh Scattering – when the **shortest wavelengths are scattered (violet and blue)– causes the "blue sky"**
  - Sunset or Sunrise– **all the blue waves scattered as the energy passes through a longer atmosphere (larger angle) red, orange, and yellow left.**


white light
directly from
the sun
blue sky from
scattered light

The Atmosphere

- **Gaseous envelope that surrounds the earth**
- **Extends outward at least 6000 miles**
- More than half of the mass of the atmosphere found **below 3.8 miles**
- More than **98% lies with 16 miles of sea level**
- **Humans are creatures of the atmosphere**

Size of the Atmosphere



Composition of the Atmosphere

- **Relative Humidity**
  - The **most familiar** of humidity measures
  - The ratio that compares the **actual amount of water vapor in the air to the water vapor capacity of the air**
    - **Capacity** is the **maximum amount of water vapor that can be in the air at a given time**
    - As the **temperature increases, relative humidity decreases**
    - As the **temperature decreases, relative humidity increases**

Structure of the Atmosphere

- **Thermal layers** of the atmosphere
  - **Troposphere and Tropopause**
    - **Lowest level**, closest to sea level
      - **11 miles at equator to 8 miles at poles**
      - **Deepest over the tropical regions**
      - **Shallow over the poles**
      - **Varies with the passages of warm and cold air**
  - **Stratosphere and Stratopause**
    - **Extends from 11 miles above sea level to 30 miles above sea level**

Upper Thermal Layers

- **Mesosphere and Mesospause**
  - Begins 30 miles and ends 50 miles above sea level
- **Thermosphere**
  - Begins at 50 miles and gradually extends out
- **Exosphere**
  - Outer most portion of the atmosphere
  - Blends with interplanetary space

Atmospheric Pressures and Circulation

- **Atmospheric pressures are simply the "weight" of the overlying air**.

- The taller the column of air the greater the pressure.
  - So at **sea level, the column of air above is longer thus the air pressure is higher, and the air is denser**
  - At a **high altitude there is a smaller column of air, so the air pressure is lower and the air is less dense**.

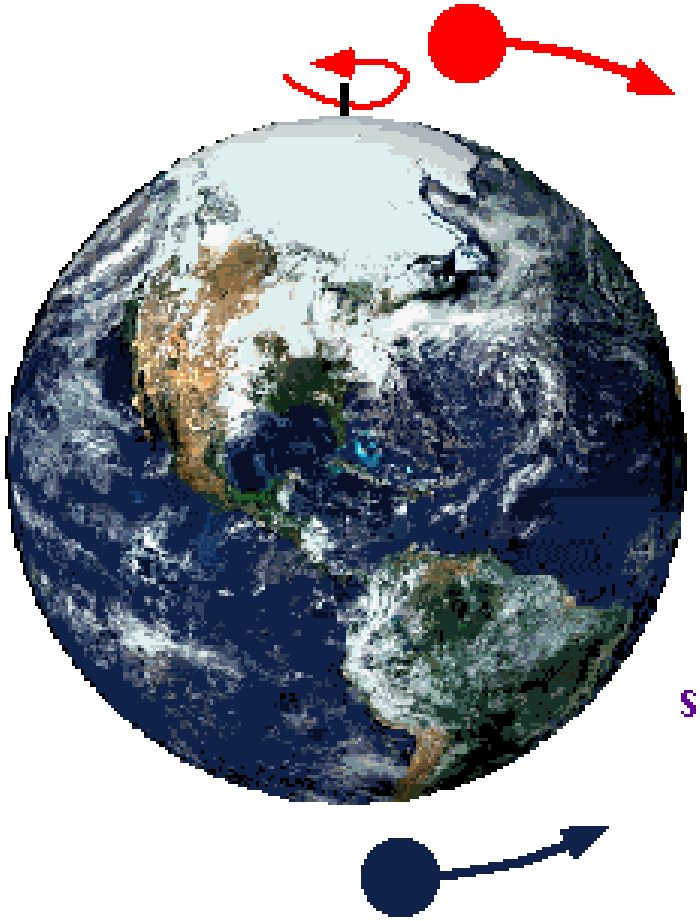
- **The decrease in air pressure decreases with altitude but not at a constant rate.**

The Coriolis Effect or Force

- **Appearance of all things drifting sideways** as a result of the Earth's rotation.
- Why? If a rocket is shot directly at New York, by the time the rocket arrives at New York, the Earth has rotated and the rocket seems to have **"drifted"**
- **Applies to any freely moving object**.

The Coriolis Effect

Caused by the earth's rotation



Objects deflect to the right in the Northern hemisphere

Objects deflect to the left in the Southern Hemisphere

Four Basic Points of the Coriolis Effect

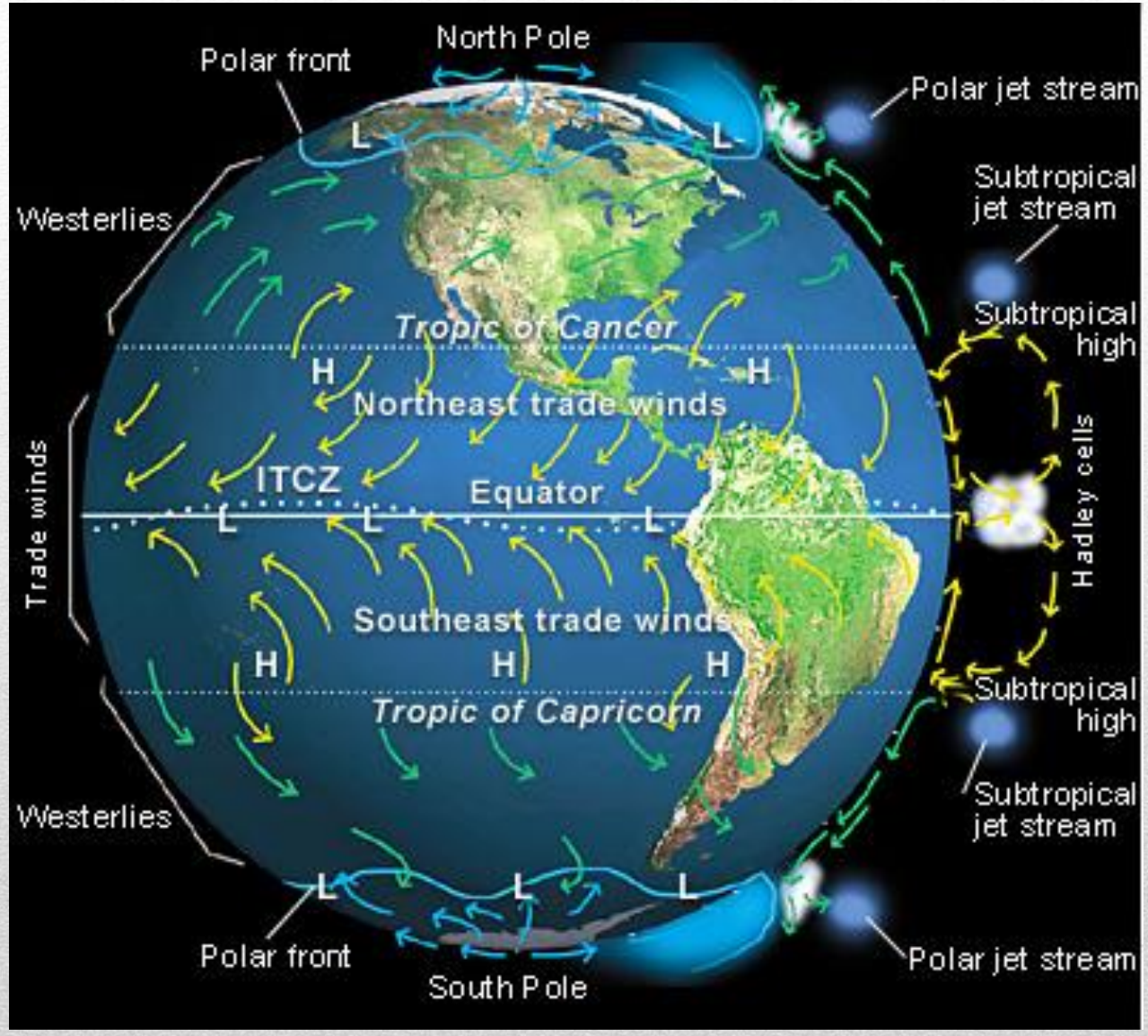
- 1. **Regardless of the initial direction of motion**, any freely moving object appears to deflect to the **right** in the **Northern Hemisphere** and to the **left** in the **Southern Hemisphere**
- 2. The apparent deflection is **strongest** at the **poles** and **decreases progressively toward the equator** where there is zero
- 3. The Coriolis effect is **proportional** to the **speed** of the object, so a **fast-moving object is deflected more than a slow one**
- 4. The Coriolis effect **influences direction of movement only**… it has **no effect on speed.**

The Nature of Atmospheric Pressure

- **Atmospheric Pressure is the force exerted by the gas molecules on some area of the Earth's surface or on any body.**
- **This pressure is exerted on every solid or liquid surface it touches**
- **It is omni-directional, exerted equally in all directions.**

Factors Influencing Atmospheric Pressure

- **Density and Pressure**
  - **Density is the mass of matter in a unit volume**
    - The density of a gas is proportional to the pressure on it and the pressure the gas exerts is proportional its density. The denser the gas, the greater the pressure it exerts.
  - **Atmosphere is held to the Earth by gravity**. So as the air moves away from the Earth, there is less gravity and less density, thus less pressure.
    - **Higher altitude, less density, less pressure**
    - **Lower altitude, higher density, higher pressure**

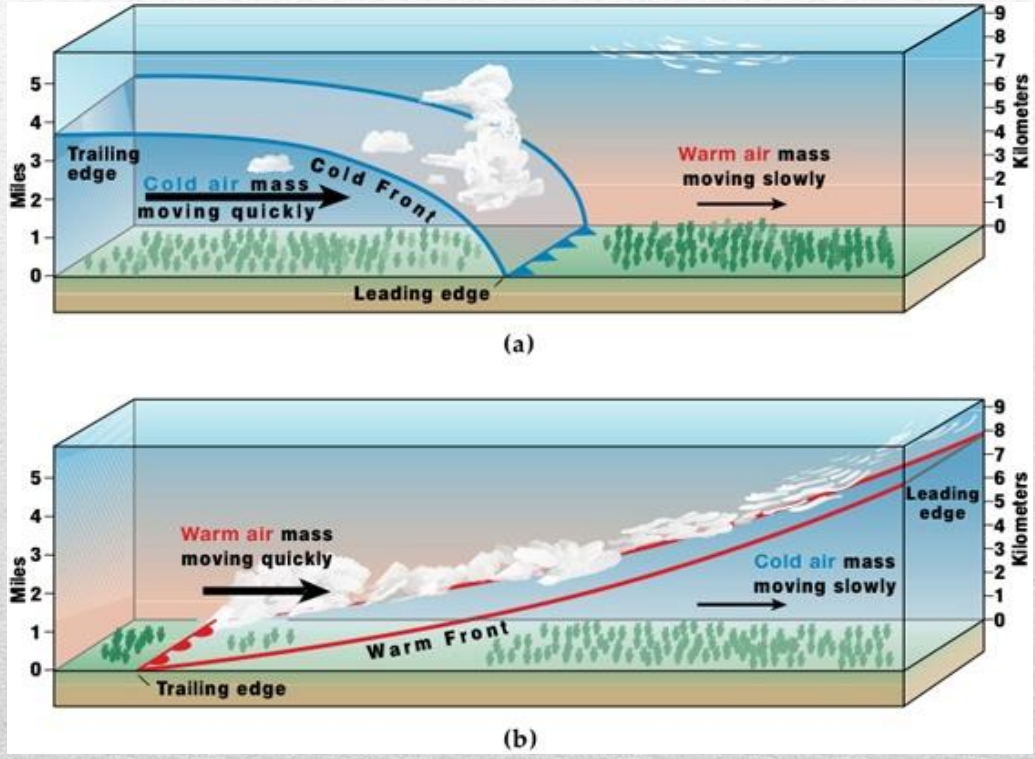

North Pole
Polar front
Polar jet stream
Subtropical jet stream
Westerlies
Subtropical high
Tropic of Cancer
H
H
Northeast trade winds
Trade winds
ITCZ
Equator
Hadley cells
L
L
L
Southeast trade winds
H
H
H
Subtropical high
Tropic of Capricorn
Subtropical jet stream
Westerlies
L
L
L
Polar front
South Pole
Polar jet stream

Buoyancy of Air

- **Atmospheric Stability**
  - **Stable air** –if a **parcel of air resists upward vertical movement**
    - Could become **unstable if a force is applied, such a topographical feature (mountain slope)**
    - **Stable air is NON-BUOYANT**
  - **Unstable air**– if it **either rises without any external force other than the buoyant force or continues to rise after such an external force has ceased to function.**
    - **Unstable air is BUOYANT**
    - **Unstable air continues to rise until it reaches temperature and density equal to itself, this is called the equilibrium level**.
  - The **intermediate condition is called Conditional Instability – between absolute stability and absolute instability**

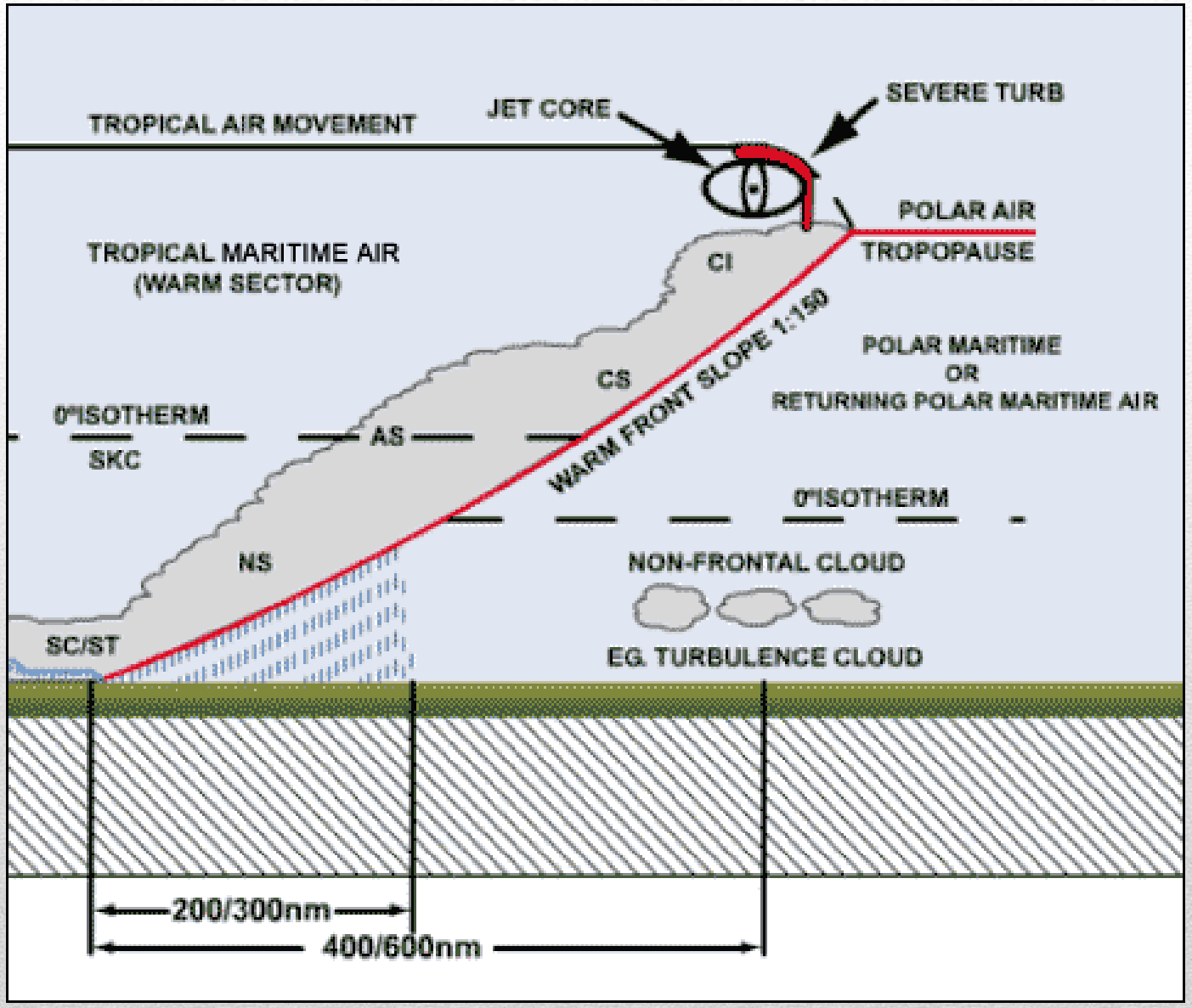
Fronts

- **Boundary between a two unlike air masses**
- **Not two dimensional boundary at the surface, but a three dimensional zone of discontinuity**
  - **Warm, Cold, Stationary, Occluded fronts**



Warm Fronts

- Forms by **advancing warm air**
- **Slope is gentle, ascends over treating cool air , decreasing adiabatically as the air rises**
- Clouds **form slowly and not much turbulence (High cirrus clouds**, moving towards a **altocumulus or altostratus**
- **Broad precipitation, protracted and gentle**


TROPICAL AIR MOVEMENT
JET CORE
SEVERE TURB
POLAR AIR
TROPOPAUSE
TROPICAL MARITIME AIR
(WARM SECTOR)
CI
CS
AS
NS
SC/ST
0°ISOTHERM
SKC
WARM FRONT SLOPE 1:150
POLAR MARITIME
OR
RETURNING POLAR MARITIME AIR
0°ISOTHERM
NON-FRONTAL CLOUD
EG. TURBULENCE CLOUD
200/300nm
400/600nm

Cold Fronts

- Forms by **advancing cold air**
- Is a **steeper front than a warm front** with a "**protruding nose**"
- **Moves faster than a warm front**
- **Rapid lifting, unstable air, blustering and violent weather**
- **Vertically developing clouds**
- If **unstable air, precipitation can be showery or violent**
- **Precipitation along the leading edge and immediately behind the ground-level position of the front.**

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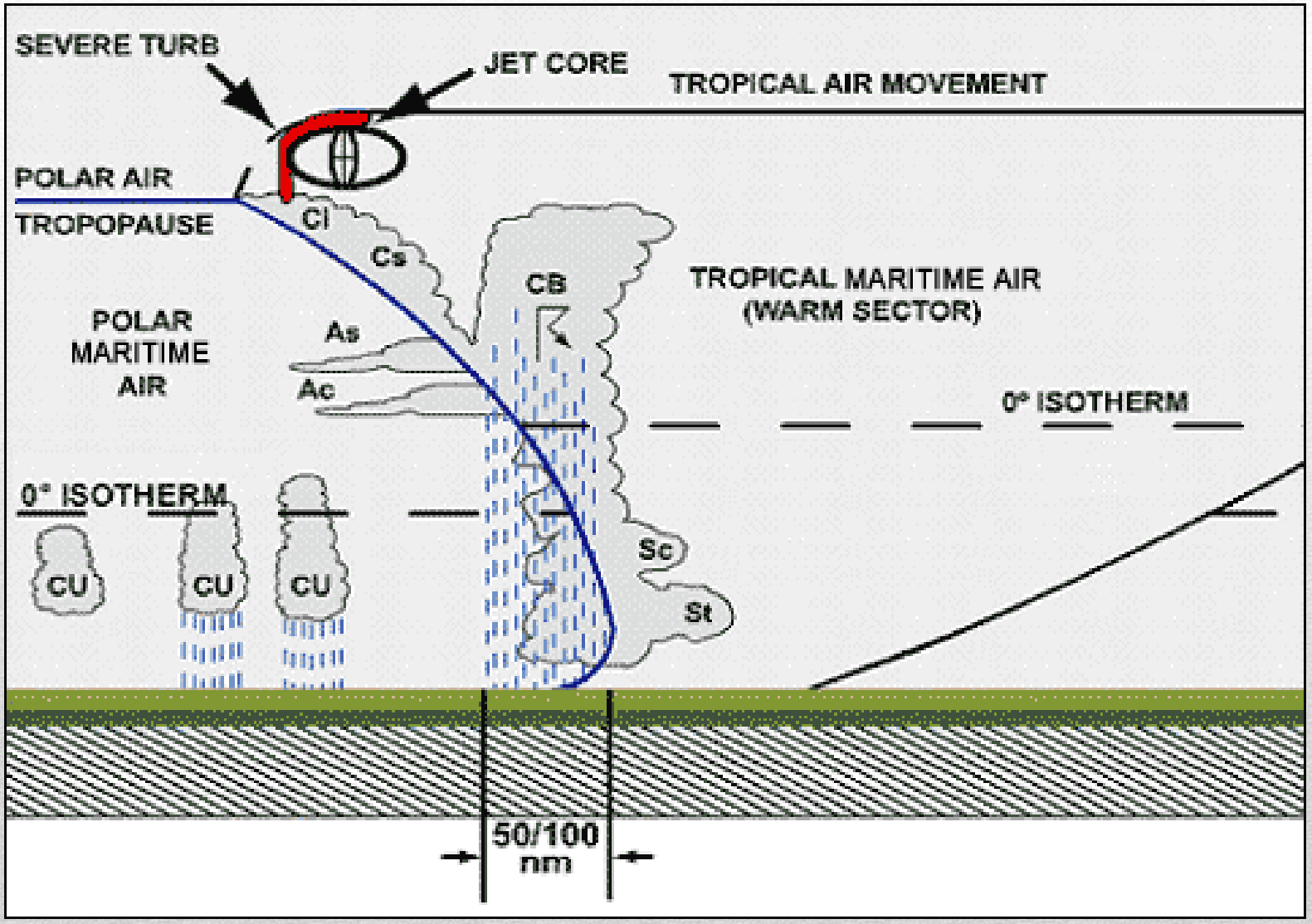
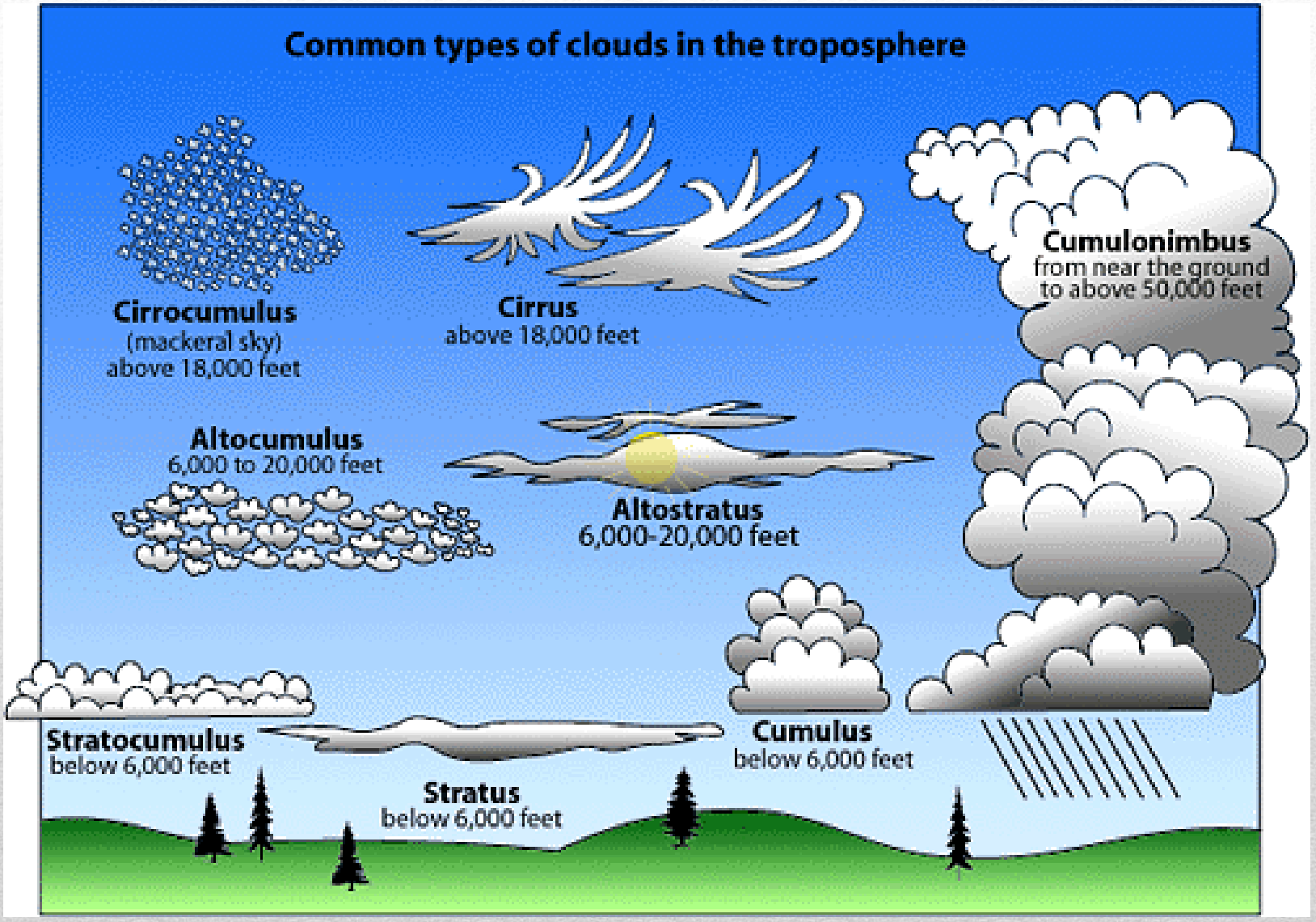

SEVERE TURB
JET CORE
TROPICAL AIR MOVEMENT
POLAR AIR
TROPOPAUSE
Cl
Cs
CB
TROPICAL MARITIME AIR
(WARM SECTOR)
POLAR
MARITIME
AIR
As
Ac
0° ISOTHERM
0° ISOTHERM
CU
CU
CU
Sc
St
50/100
nm

Clouds

- **Classifications of Clouds**
  - **Cirriform** – thin and wispy and composed if ice crystals
  - **Stratiform** – appear as a grayish sheets that cover most or all of the sky, rarely being broken up into individual cloud unites
  - **Cumuliform** – massive and rounded, usually with a flat base and limited horizontal extent but often billowing upward to great heights

Clouds

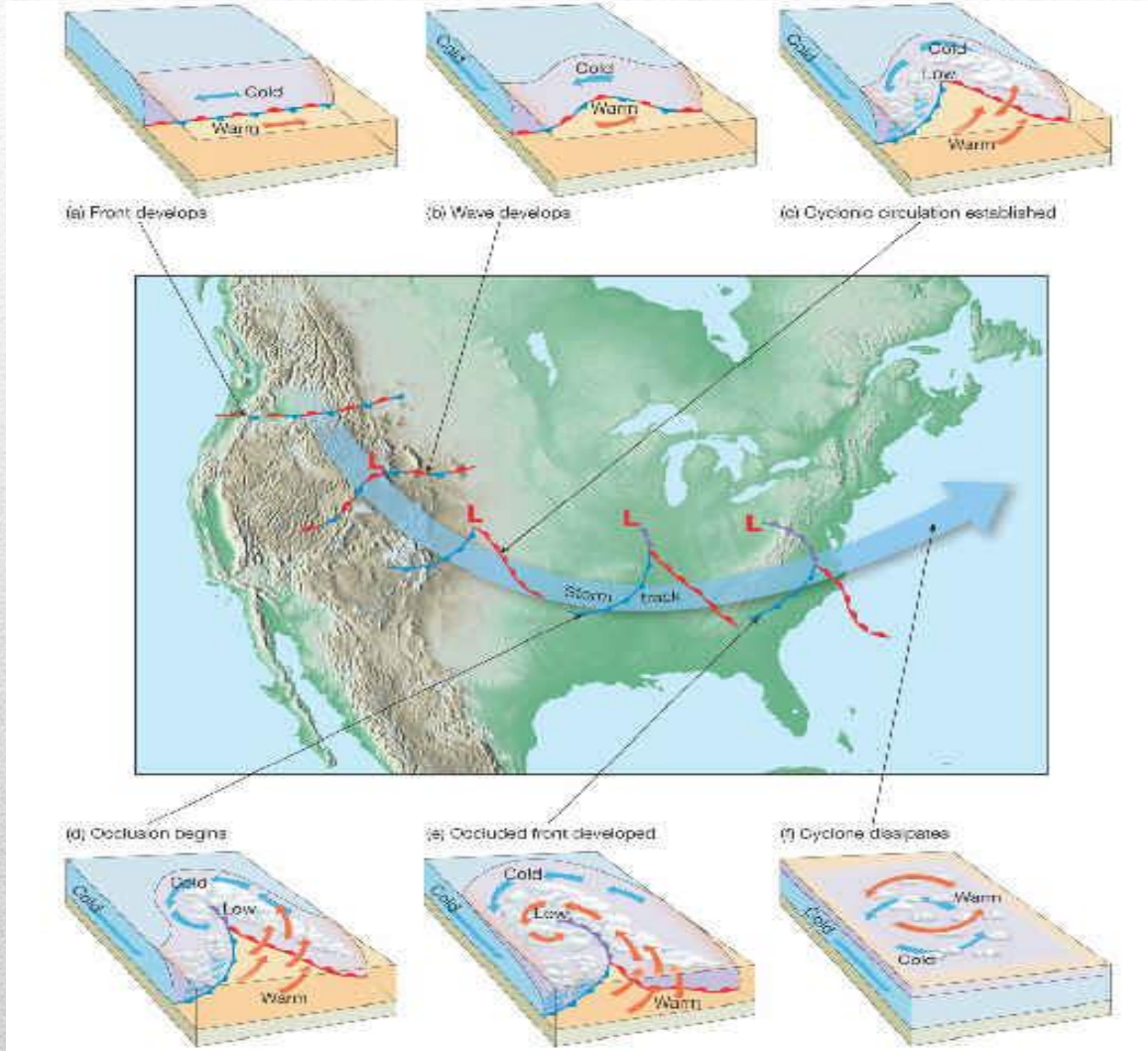
- **High– Found 20,000 Feet**, Small amount of water vapor and low temperature, and ice crystals
  - **Cirrus, cirrocumulus, cirrostratus**
- **Middle– 6500 to 20,000 feet**, composed of liquid water
  - **Altocumulus, Altostratus**
- **Low– 6500 feet**, often appear as individual clouds, but often appear as a general overcast, somber skies and drizzly rain
  - **Stratus, Stratocumulus, Nimbostratus**
- **Vertical**– grows upward from low bases to **heights of 60,000** ft., very active vertical movements, usually associated with fair weather, or storm clouds
  - **Cumulus, Cumulonimbus**


Common types of clouds in the troposphere
Cirrocumulus
(mackeral sky)
above 18,000 feet
Cirrus
above 18,000 feet
Cumulonimbus
from near the ground
to above 50,000 feet
Altocumulus
6,000 to 20,000 feet
Altostratus
6,000-20,000 feet
Stratocumulus
below 6,000 feet
Cumulus
below 6,000 feet
Stratus
below 6,000 feet

Impact of Storms on the Landscape

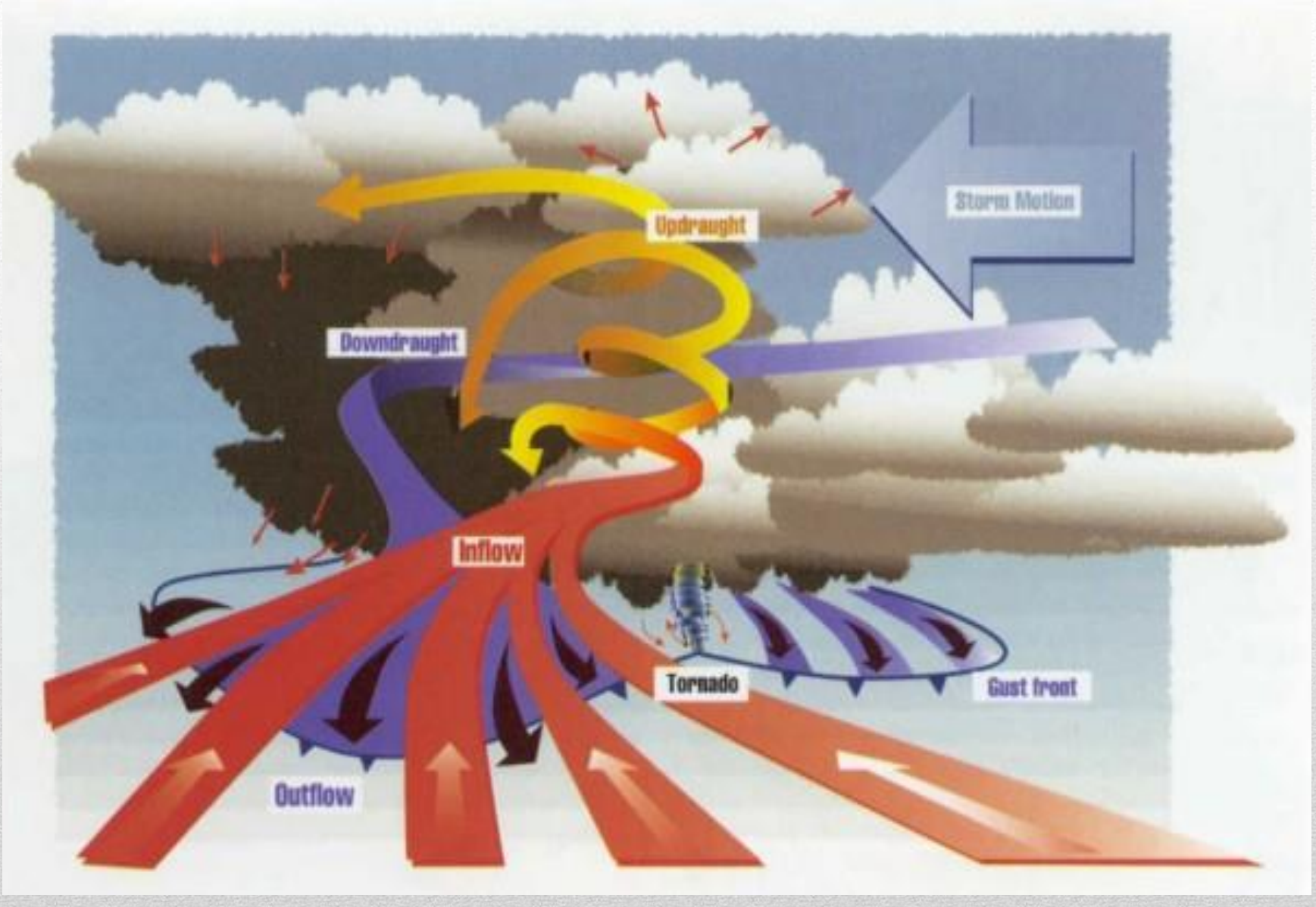
- **Storms influence our lives everyday**
- **Storms impact the landscape**
  - **Negative effect**
    - Accelerate erosion,
    - Flood valleys,
    - Destroy buildings
    - Decimate crops
  - **Positive effect**
    - Promote diversity in vegetative cover
    - Increase the size of lakes and ponds
    - Stimulate plant growth with moisture

Life Cycle of the Mid Latitude Cyclones



Localized Severe Weather

- **Thunderstorms**
  - **Defined as a violent convective storm accompanied by thunder and lightning**
  - **Found frequently found in conjunction with other kinds of storms**
  - **Triggered by unstable uplift**
  - **Formation called the cumulus stage**
  - **Mature stage – in which updrafts and downdrafts coexist as the cloud continues to enlarge** – heavy rain accompanied with hail, blustery winds, lighting, and the growth of the anvil top
  - **Dissipating stage -- with light rain ending the turbulence.**


Storm Motion
Updraught
Downdraught
Inflow
Tornado
Gust front
Outflow

Localized Severe Thunderstorms

- **Severe Thunderstorms can have**
  - **Wind exceeds 58 mph**
  - **Hailstones larger than ¾ of an inch**
  - **Generates a Tornado**
- **Conditions to create a sever thunderstorm are**
  - **Changes in wind shear**
  - **High water-vapor content**
  - **Updraft of air**
  - **The existence of a dry air mass above a moist air mass**
  - **Most important is the *Vertical wind shear***
  - ***The most damaging is the supercell storm***
  - **Hailstones can be a hazard from a thunderstorm**
- **Hailstones-cause more damage than casualties**

Tornadoes

- **Very small and localized**
- **Most destructive of all atmospheric disturbances**
- **Most intense vortex in nature , deep low pressure cell surrounded by a violently whirling cylinder of wind**
- **Less than a quarter of a mile in diameter but most extreme pressure gradients known** (100-millibar difference from the center to the edge.
- **Upswept water vapor condenses into a funnel cloud**
- **Advances along an irregular track that generally extends from southwest to northeast in the US**
- **Fujita tornado intensity scale for intensity**
- **Formation – develop in the warm moist unstable air associated with a mid latitude cyclone, along the squall line**
- **Develops out of mesocyclone, but only about half of all mesocyclones formed result in a tornado**
- **More than 90 % of tornadoes happen in the US in Tornado Alley**

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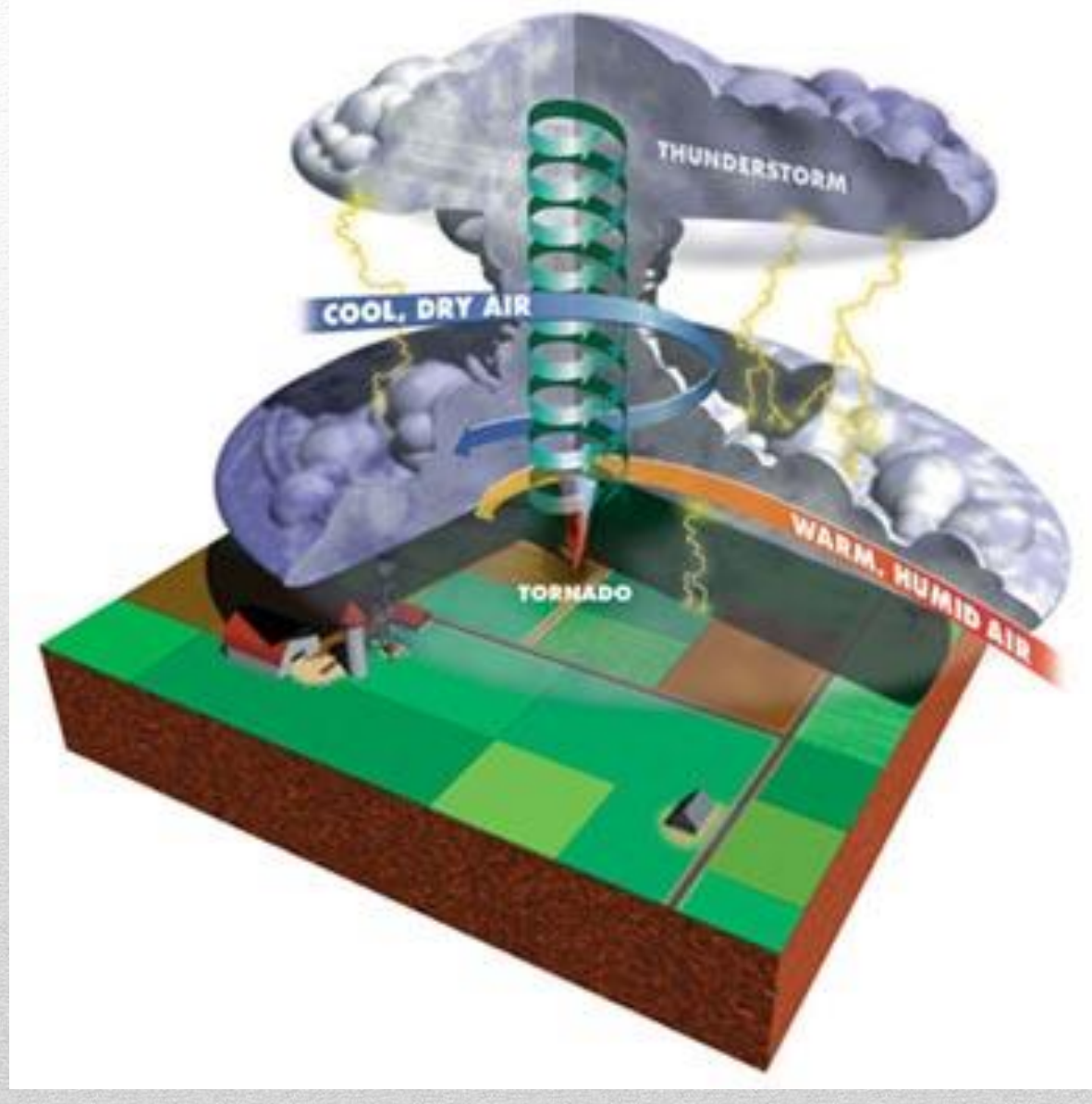

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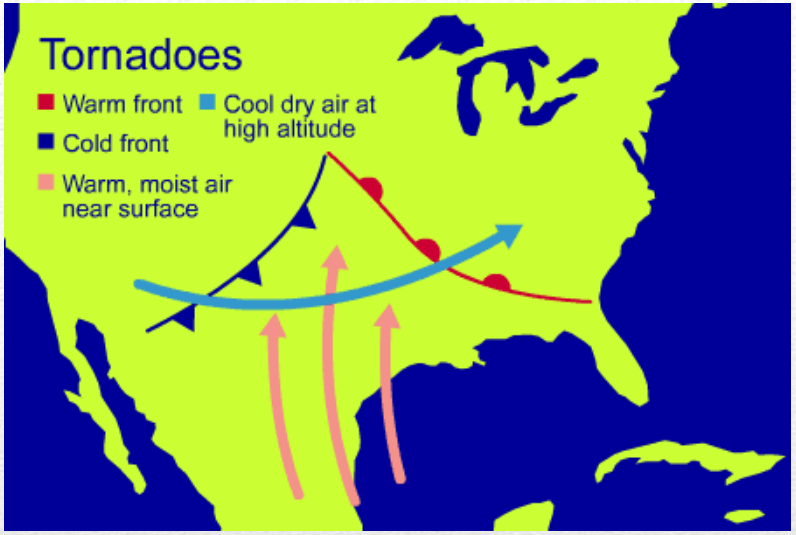
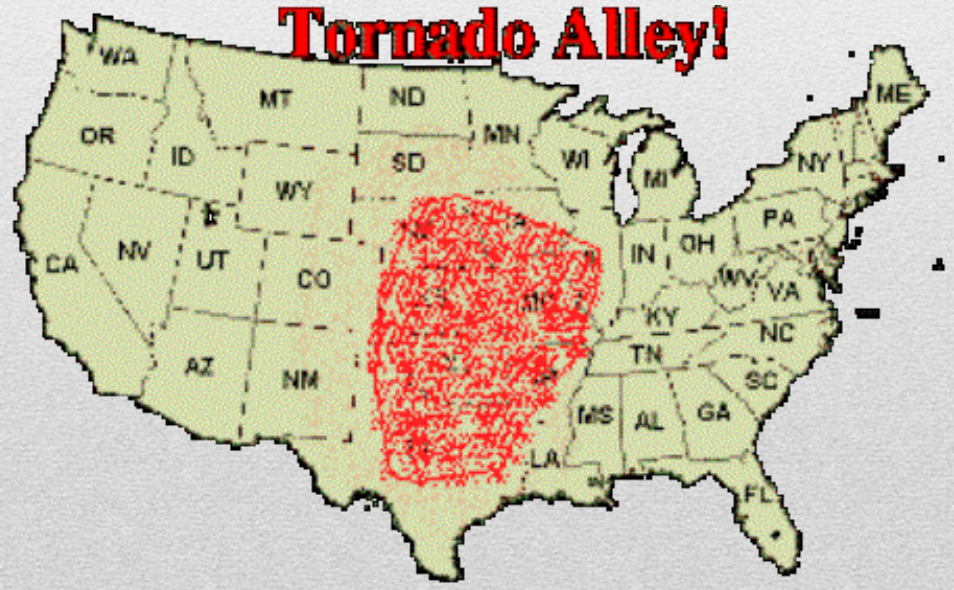
Westerly winds
at high levels
bring cool, moist
air from Pacific
Southwesterly winds
at mid-levels bring hot
dry air from Mexico deserts
Southerly winds at suface
bring warm, humid air from
Gulf of Mexico


Tornadoes
Warm front
Cool dry air at
high altitude
Cold front
Warm, moist air
near surface


Tornado Alley!
WA
OR
CA
ID
NV
MT
WY
UT
AZ
CO
NM
ND
SD
MN
NE
KS
OK
TX
IA
MO
AR
LA
WI
IL
MS
MI
IN
KY
TN
AL
OH
WV
GA
FL
SC
NC
VA
PA
NY
ME

Tornadoes

Blizzards and Ice Storms

- **Blizzards-** Severe winter storms
  - Large amounts of falling snow
  - High Winds
  - Long lasting
  - Low visibilities
  - Extended periods of time
  - Often whiteouts because of the snow
  - Cold temperatures
  - Found across the country, extremely hazardous in the midland of the US
  - In the east, they can be called *nor'easters*
  - Extremely dangerous because of the wind chill

Blizzards and Ice Storms

- **Ice Storms**
  - Prolonged periods of freezing rain
  - Develop mostly in the north side of a stationary or warm front
  - Three conditions happen for Ice Storms to happen
    - Ample source of moisture in warm front
    - Warm air uplifted over shallow layer of cold air
    - Objects on the land surface close to freezing
  - Everything covered with ice
  - Often found in the mid-west or east

Fog

- **A Cloud on the ground**
  - **Radiation fog** – results when the ground loses heat through radiation usually at night.
  - **Advection fog** – develops when warm, most air moves horizontally over a cold surface, such as snow-covered ground or cold ocean current
  - **Upslope fog or orographic fog--** by adiabatic cooling when humid air climbs a topographic slope
  - **Evaporation fog**– results when water vapor is added to cold air that is already near saturation.

Drought, Mountain Windstorms

- **Hazards created by wind and lack of rain**
  - **Drought**
    - Extended period of unusually low precipitation that produces a temporary shortage of water for people, other animals, and plants
    - More than 1 billion people around the world live in arid areas
      - Contribute to food shortages-causes famine
      - Water shortages
      - Power shortages
      - Decrease in industrial productivity
  - **Mountain Windstorms**
    - Strong winds, usually in the winter, which blow down the downward sides of mountains

Dust and Sand Storms, Heat Waves

- **Hazards created by wind and lack of rain**
  - **Dust and Sand Storms**
    - Strong windstorms carrying suspended dust causing low visibility for a long period of time
  - **Heat Waves**
    - Prolonged periods of extreme heat
      - Both longer and hotter than the year before
      - Happen under prolong high pressures
      - Responsible for many deaths from 1992 on

Linkages with Other Hazards

- Severe weather is linked to other hazards
  - Flooding
  - Mass movements
  - Wildfires
  - Long-term global climate change
  - Lightening

Natural Service Functions of Severe Weather

- There are some natural service functions of severe weather
  - There are long term services
    - Lightening from a thunderstorm can start a wildfire, which can revitalize a forest or prairie
    - Windstorms can help maintain the health of forests
    - Ice storms are a natural ecological cycle that increases plant and animal diversity in the forest
  - In the hydrological cycle, severe weather are a primary source of water
  - Humans can benefit from severe weather by enjoying a lightening show, watching a snowstorm, and watch a tornado chaser in a movie describe how they can be dumb being in the middle of a tornado

Minimizing Severe Weather Hazards

- **Severe weather will continue to threaten humans, because we can't "fix stupid"**
- **But if we as humans work at it, we can lessen the damage and loss of life**

Forecasting and Predicting Weather Hazards

- **There are many ways to forecast and predict the weather.**
  - **Use of the Doppler Radar** stations are used to predict severe weather
  - **Watches and Warnings** are posted for severe weather-if followed there can be less damage and loss of life
  - All of these **new prediction abilities** can always predict all the weather, humans have to be aware of their surroundings and act accordingly

Adjustment to the Severe Weather Hazard

- **Although we can't control the climate, there are two ways we can reduce the loss of life and property**
  - **Mitigation activities**
    - Using safety-conscious engineering in building structures
    - Installing warning systems
    - Establishing hazard insurance
  - **Preparedness and Personal Adjustments**
    - Establishing community and individual plans and procedures to deal with an impending natural hazard